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# STRENGTH AND BEHAVIOR OF HIGH VOLUME FLY ASH AND REPLACEMENT OF SAND BY QUARRY DUST

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**ABSTRACT**

*Fly ash is one of the naturally-occurring products generated by coal-burning power plants, composed of the fine partials that are driven out of the boiler with flue gasses. The manufacturing of Portland cement- which places a key role in concrete creates a lot of carbon dioxide. One of the strategies for diminishing concrete influence of the environment is the utilization and replacement of cement by fly ash. This paper deals with the behavior and strength of high volume fly ash concrete and partial replacement of sand by quarry dust. The ordinary Portland cement replacement by different percentages like 40%, 50% and 60% with fly ash. To find out the split tensile strength, flexural strength and compressive strength. Based on testing results comparison between conventional concrete and high volume fly ash concrete (HVFAC), high volume fly ash concrete gives more strength than conventional concrete and this HVFAC very cheap than conventional concrete.*

**Keywords:** Fly ash, quarry dust, Ordinary Portland cement, flexural strength, high volume fly ash concrete.

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## 1. INTRODUCTION

Fly ash is one of the naturally-occurring products generated by coal-burning power plants, composed of the fine partials that are driven out of the boiler with flue gasses. The manufacturing of Portland cement- which places a key role in concrete produces a huge volume of carbon dioxide. One of the strategies for diminishing concrete influence of the environment is the utilization and substitution of cement with fly ash. The halfway supplanting of concrete

with fly ash remains gave high strength compared to conventional concrete up to 50% at all strength like compressive strength and splits strength and based on testing results the flexural behavior of reinforced Prism is high compared to nominal concrete nothing but conventional concrete. The crack reinforced Prism was less and deflection is less associated to traditional concrete. And the strength parameters are also similar to conventional concrete. Quarry dust is a partial replacement for sand; it gives same strength at all trail mixes (Dan Ravina 1996, Soman et al., 2014). G. Venkatesan et al., (2013), the flexural performance of conventional concrete and high volume Fly ash concrete for a various ratio of replacement of fly ash with cement, the modulus of rupture is calculated and the results were compared. In comparison, it was noted that for both conventional and high volume fly ash concrete, the0. 375d spacing of stirrups gives a better result for confinements and regarding economy about 50 % savings in cement and 13% in steel is saved by modifying fly ash - cement ratio. D. Bhuvaneswari et al., 2016, the high volume fly ash concrete with quarry dust gave high Durability compared to conventional concrete and it is good weather resisting manager at all types of wet and dry control mixes.

# 2. MATERIALS AND METHODS

## 2.1. Preliminary investigation

The Initial examination comprises of test predictable materials, advancement of fly ash blended concrete and assurance of new and hardened properties of Fly ash and OPC.

## 2.2. Materials

Cement utilized as a part of all blends OPC (43 review), which adjusts to IS specifications. A fundamental research facility test directed on the cement like initial and final setting time, fineness test, consistency test as per IS 8112-1989 code. The sand is collected from the Krishna River, located from nearby Vijayawada; this comes under the zone- III. Physical properties as per IS 383-1970 code recommendations are determined. Specific gravity, fineness modulus, density and void ratio of sand is 2.6, 3.1, 1.68gm/cc and 0.55. The quarry dust collected from Local crushers. This is passing from 4.75mm sieve. Physical properties as per IS383-1970 code recommendations are to find out the Specific gravity and fineness modulus of quarry dust, density, and void ratio is 2.57, 2.41, 1.85gm/cc and 0.42. The 20mm size of coarse aggregate is used for tests conducting laboratory. The coarse aggregate physical properties are calculated as per IS 383-1970code and are 2386 Part III-1963 code recommendations. The coarse aggregate of specific gravity is 2.26 and pH value of water is 7. The casting and curing test specimens are using the same quality of water, for this water collecting from KL University. The Sulphonated Naphthalene formaldehyde superplasticizer used for these tests. It is powerful water reducing agent and excellent dispersing agent. The dosage is used for 2% of powder content. It reduces the heat of hydration and it can significantly improve the early and late strength grade of concrete. For this study using HYSD 500 steel, 8, 10 and 12 mm bars are used. 8mm bars used as stirrups. The fly ash is taken from NTPC, which is located in Ibrahimpatnam nearby Vijayawada. Selected Class F fly ash is used for conducting experiments for various percentages. IS 456-2000 code identifies that fly ash following to grade I of IS 3812-1981code is used for mixing Portland cement of partial replacement. The properties of physical and chemical for fly ash are indicated in Table 1 and 2 and these values are taken from previous paper and mentioned in Table 1 and Table 2 and the values are taken from soman (1).

**Table 1** Fly Ash- Chemical properties

| Sl. No | Components | Percentage | Sl. No | Components | Percentage |
|---|---|---|---|---|---|
| 1 | SiO2+Al2O3+Fe2O3 | 94.25 | | | |
| 2 | Sulphur trioxide - SO3 | 0.71 | 9 | Calcium oxide (CaO) | 1.94 |
| 3 | Sodium oxide - Na2O | 0.26 | 10 | Free CaO Nil | Nil |
| 4 | Loss On Ignition | 0.38 | 11 | Reactive CaO | 1.44 |
| 5 | Silica -SiO2 | 59.90 | 12 | Chloride (Cl) | 0.009 |
| 6 | Alumina - Al2O3 | 30.81 | 13 | Magnesium oxide (MgO) | 0.36 |
| 7 | Iron - Fe2O3 | 3.83 | 14 | Manganese dioxide as MnO2 (mg/Kg) | 12.38 |
| 8 | Reactive SiO2 | 30.01 | 15 | Potassium oxide as K2OP2O5 (mg/Kg) | 0.031 |

**Table 2** Fly Ash - Physical properties

| Sl. No | Physical Parameters | Values |
|---|---|---|
| 1 | 325Mesh sieve - Fineness residue retained (%) | 9.02 |
| 2 | Content of moisture (%) | 0.080 |
| 3 | 28 days compressive strength with OPC (%) | 91.90 |
| 4 | Time of setting Initial (OPC/Pfa) (minutes) | 150/170 |
| 5 | Le Chateliers expansion- Soundness (mm) | 0.70 |
| 6 | Density (kg/cum) | 2150 |

## 3. MIX PROPORTIONS

The mix proportion is designed under the guidelines of IS 10262-2009. Partial replacement of fly ash with different mix proportions like 40%, 50% and 60% and fine aggregate is replaced sand by quarry dust with 50% of weight. The quantity materials are required for this study is indicated in Table 3.

### 3.1. Quantity of materials required

**Table 3** Mix proportions and Material necessities

| Components | F0 | F40 | F50 | F60 |
|---|---|---|---|---|
| Cement (kg/m$^3$) | 350 | 210 | 175 | 140 |
| Fly ash (cum) | 0 | 0.054 | 0.06 | 0.081 |
| Water (lit) | 140 | 120 | 120 | 120 |
| Fine aggregate (cum) | 0.28 | 0.14 | 0.14 | 0.14 |
| Coarse aggregate (cum) | 0.478 | 0.478 | 0.478 | 0.478 |
| Super plasticizer (lit) | 0 | 7 | 7 | 7 |
| Quarry dust (cum) | 0 | 0.14 | 0.14 | 0.14 |

## 3.2. Tests conducted on specimens

### *3.2.1. Compressive strength*

Cubes are used for this compressive strength test. The cube dimensions are 150X150X150mm. Totally 60 number of cubes were cast for M40 mix design as per IS 10262-2009. Mix proportioning is 1: 2.1:2.85 for M40 mix grade. Compressive testing is done in 3, 7, 28, 56 and 90 days. This test is conducted on the universal testing machine.

### *3.2.2. Split tensile strength*

Cylinders are used for this split tensile strength test. The cylinder dimensions are 300X150mm. Totally 60 number of Cylinders were cast for mix design as per IS 10262-2009. Mix proportioning is 1:2.1: 2.85 for M40 mix grade. The results are taken at the age of 3, 7 and 28 days. From the equation (1) to determine the split tensile strength

$$\text{Split tensile strength} = \frac{2P}{\pi d l} \qquad (1)$$

Where p is applied load
d is the cylinder diameter
l is the cylinder height

### *3.3.3. Modulus of Rupture*

Modulus of Rupture is done in 28 days. To determine Modulus of Rupture value by using formula (2). As per IS 456-2000 Modulus of Rupture is nothing but modulus of rupture "m"

$$\text{Modulus of Rupture } m = \frac{Es}{Ec} \qquad (2)$$

Where
$E_s$ is the modulus of elasticity of steel
$E_c$ is the static modulus of elasticity (N/mm$^2$)

### *3.3.4. Flexural strength*

Prisms are used for determining the flexural strength. The dimensions of the Prisms are 100X100X500. The results are taken at the age of 3,7 and 28 days. The experiments were conducted in the laboratory and calculated to the HVFAC Prisms of the flexural reaction of reinforced and to associate its performance with that of comparable regular reinforced concrete Prism.

Based on compressive and split tensile strength results replacement of cement by 40% of fly ash will give high strength at the age of 28,56 and 90 days. So, the Prisms are cast at 40% replacement of fly ash. The Prisms were cast with different percentages, including oiling the sides of the mold surfaces before concreting.

The models are cast in iron models concrete is mixed by manually in the laboratory premises. With the help of mechanical vibration, the Prisms are vibrated. After 24 hours the frameworks of Prisms are released. After casting the Prisms are cured by laboratory water tanks.

# 4. TEST PROCEDURE

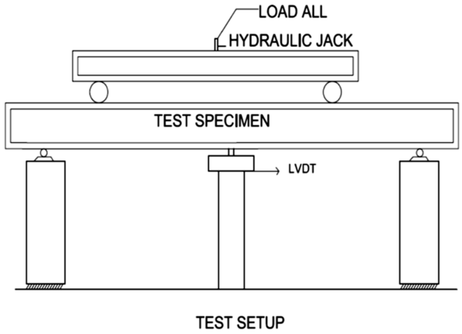


**Figure 1** Test setup of the Prism tests in compression under two points loading.

## 4.1. Casting and compacting

Prisms were cast as per the above specifications for conventional concrete and high volume fly ash concrete. The size of the finished surface of the prism was maintained to 100X100X500 mm. Care was taken to avoid segregation of aggregates and laitance. The test specimens of moulds carefully removed and stored in water tubs for curing. The specimens were not allowed to dry at any time until they had been tested and the test setup is shown in Fig 1.

## 4.2. Method of testing of RC Prism specimen:

The cured concrete Prisms were tested after 3, 7 and 28 days of curing at room temperature. Loads were applied by two point load method. Loads were applied carefully with rollers which were placed above the specimens at 20cm apart. The loads will divide equally between the two loading rollers.

As per IS 516-1959. The flexural strength can be calculated by using equation 3.

Flexural strength = $\frac{PL}{BD^2}$ (3)

Where

P is the Failure of Load

L is the Prism Length (500 mm)

B is the Breadth of Prism (100 mm)

D is the Width of Prism (100 mm)

# 5. RESULTS AND DISCUSSION

For this study, M40 grade mix proportion is used and the mix ratio is 1: 2.1: 2.85. For compressive strength totally 45 cubes were cast. The average of 3 cubes for every age of testing should be recorded. The compressive strength results are indicated in Fig. 2, the graph indicates that for 28 days compressive strength of HVFAC is less when compared to conventional concrete that means for 28 days conventional concrete is 50.98 N/mm$^2$ and HVFAC is 49.88 N/mm$^2$and after 28 days the compressive strength of HVFAC compressive strength value is continuously and significantly increase than conventional concrete that means for 90 days the compression value for conventional concrete is 51.38 N/mm$^2$ and the HVFAC is 52.14 N/mm$^2$.

The split tensile strength results were mentioned in Fig. 3, the group said that for split tensile strength totally 27 cylinders were cast. For results tested 3 cylinders for each sample, specimens should be recorded at the age of 3, 7 and 28 days. For 28 days the split tensile strength of conventional concrete has been 2.1 N/mm$^2$ and the HVFAC is 2.37 N/mm$^2$.

Modulus of Rupture of concrete is tested at the age of 28 days. Based on the IS 516-1959 code took those values of Modulus of Rupture values mentioned in Table 5.

The Flexural strength of the concrete Prism is tested at the age of 28 days of conventional concrete and HVFAC at F40 percentage because of the compressive and split tensile strength tests shows that the 40% of replacement of cement by fly ash give high strength compared to conventional concrete. Totally 12 Prisms are being cast to determine flexural strength in that 6 conventional concrete Prism and 6 HVFAC Prisms. The three test specimens were tested and took an average of three results. The test results are shown in Table 4. The strength results are nothing but Modulus of Rupture and flexural strength results are shown in Table 5 and Fig 4 indicates that Flexural strength of concrete at different ages.

**Table 4** Strengths of hardened concrete

| S. No | Properties | Age of testing (days) | F0 ($N/mm^2$) | F40 ($N/mm^2$) | F50 ($N/mm^2$) | F60 ($N/mm^2$) |
|---|---|---|---|---|---|---|
| 1 | Compressive strength | 3 | 23.11 | 18.22 | 17.77 | 16.44 |
| | | 7 | 27.8 | 24.77 | 19.6 | 17.78 |
| | | 28 | 50.13 | 49.88 | 45.77 | 40.05 |
| | | 56 | 50.98 | 51.86 | 46.76 | 40.98 |
| | | 90 | 51.38 | 52.14 | 47.38 | 41.67 |
| 2 | Split tensile strength | 3 | 1.6 | 1.42 | 0.89 | 0.70 |
| | | 7 | 1.8 | 1.61 | 1.38 | 1.21 |
| | | 28 | 2.1 | 2.37 | 2.2 | 2.07 |

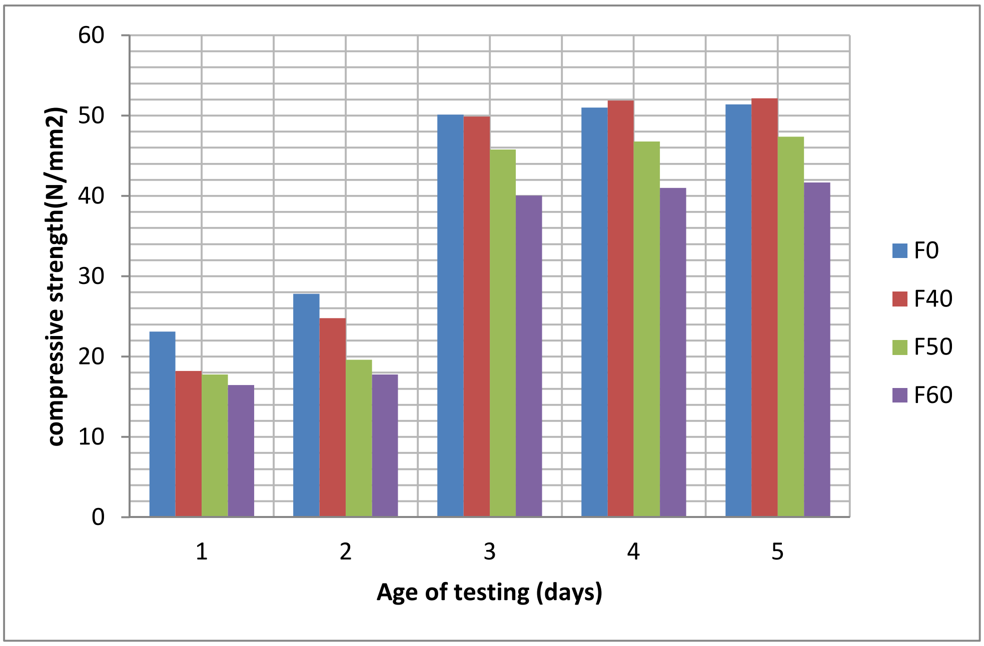


**Figure 2** Difference of Compressive Strength with different Mixes

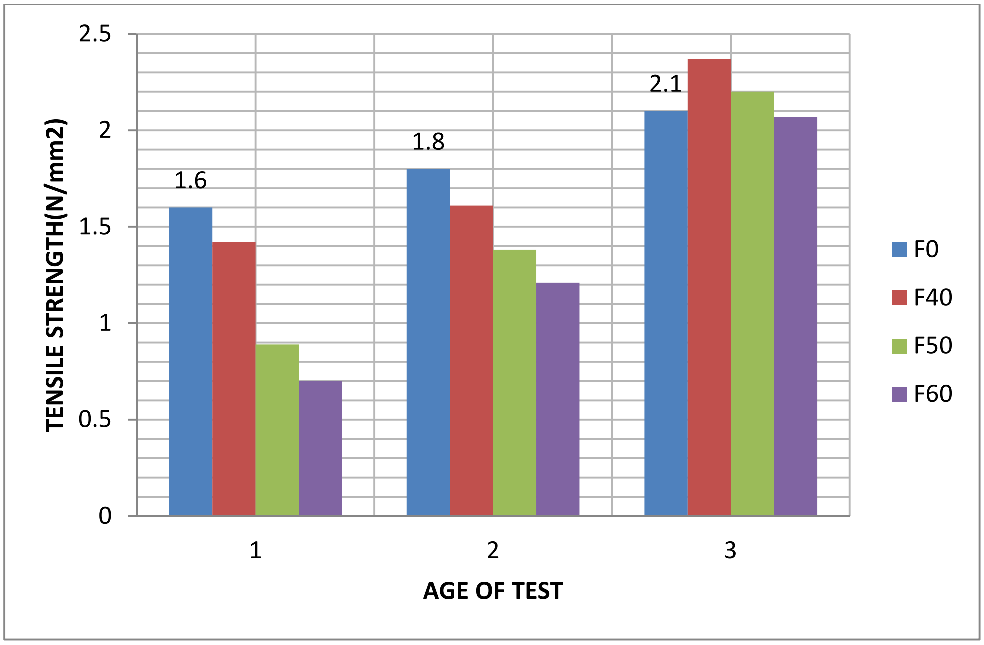


**Figure 3** Difference in Split Tensile Strength with different Mixes

**Figure 4** Flexural strength of concrete at different ages

**Table 5** Strengths of hardened concrete

| S. No | Properties | Age of testing (days) | F0 (N/mm$^2$) | F40 (N/mm$^2$) |
|---|---|---|---|---|
| 1 | Modulus of Rupture | 28 | 5.58 | 5.54 |
| 2 | Flexural strength | 28 | 13.34 | 15.13 |

## 6. COST COMPARISON OF ALL MIX PROPORTIONS

The price of cement per cubic meter concrete is contemplated. From the mixture percentage of OPCC and HVFAC used in this analysis, it is marked that is one cubic meter of concrete. The Cost comparison of all mixes is presented in Table 6.

**Table 6** Cost Comparison of all mixes

| S.no | Designation | Unit rate | Quantity of F0 | Price of F0 in Rs | Quantity of F40 | Price of F40 in Rs | Quantity of F50 | Price of F50 in Rs | Quantity of F60 | Price of F60 in Rs |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Cement (in Kgs) | 4 | 350 | 1400 | 210 | 840 | 175 | 700 | 140 | 560 |
| 2 | Fly ash(in cum) | 72 | 0 | 0 | 0.054 | 3.888 | 0.06 | 4.32 | 0.081 | 5.832 |
| 3 | F.A (Cum) | 462 | 0.28 | 129.36 | 0.14 | 64.68 | 0.14 | 64.68 | 0.14 | 64.68 |
| 4 | C.A (Cum) | 1210 | 0.44 | 532.4 | 0.478 | 578.38 | 0.478 | 578.38 | 0.478 | 578.38 |
| 5 | SP (Lit) | 15 | 0 | 0 | 7 | 105 | 7 | 105 | 7 | 105 |
| 6 | Q D (Cum) | 147 | 0 | 0 | 0.14 | 20.58 | 0.14 | 20.58 | 0.14 | 20.58 |
| Total | | | 2061.76 | | 1612.53 | | 1472.96 | | 1334.47 | |

## 7. CONCLUSIONS

- The concrete workability is improved by the addition of Fly Ash.
- Comparison of compressive strength in both conventional concrete and HVFAC, HVFAC at 40% replacement of Fly Ash concrete gave high strength after 28 days than conventional concrete.
- The results at 56 and 90 days indicate that the HVFAC 40% gave an uninterrupted and strength improvement after 28 days.
- Split tensile strength increased up to 40% replacement of fly ash. This could be attributed to the pozzolanic action due to fly ash after the strength will go down.
- Based on testing results the strength of HVFAC at 40% gave high tensile value compared to conventional concrete.
- The HVFAC 40% and conventional concrete the split tensile value for 28 days are 2.1 N/mm$^2$ and 2.37 N/mm$^2$.
- Based on experimental results the usage of sulphonated naphthalene formaldehyde the setting time of concrete is less compared to conventional concrete.
- The cost comparison reveals that the 40%replacement of fly ash concrete is 22% cheaper than conventional concrete and gives more strength compared to target mean strength of conventional concrete i.e. 48.25 N/mm$^2$.
- Relatively 50% fly ash concrete also considerable. The cost variance is 28.36% cheaper than OPC and strength similar to target mean strength.

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